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Meteorological factors association with under-five children diarrhea incidence in central Gondar zone, Northwest Ethiopia. A time series study

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Abstract

Background Under 5 children diarrhea has been one of the major public health concerns in countries with limited resources such as Ethiopia. Understanding the association between under-5 diarrhea and meteorological factors will contribute to safeguarding children from adverse health effects through early warning mechanisms. Thus, this study aimed to explore the association between under-5 diarrhea and meteorological factors to reduce health risks.

Methods A time-series ecological study was used to explore the association between meteorological factors and under-5 diarrhea incidence. Spearman's correlation was computed to test the correlation and a negative binomial regression model was fitted to determine the associations of meteorological factors with under-5 diarrhea incidence. The multicollinearity was checked using the variance inflation factor (VIF) before the multivariable regression analysis and the value was 5. aIRRs with 95% CIs and a significance level of 0.05 were used for all the statistical tests. Statistical analyses were conducted using STATA 14.2 software.

Results The highest under-5 diarrhea incidence morbidities was 180.9 per 1000 per year for under-five children. This study revealed a positive and negative correlation between the count of under-5 diarrhea and average monthly temperature and rainfall at 0 and 2 lag months with RRs of 1.0209 (95% CI: 1.0034–1.0387), RR 1.0202(95% CI:1.0022–1.0385), RR 0.999(95% CI:0.9985–0.9996), and RR 0.9992(95% CI:0.9987–0.9997) respectively.

Conclusion There was an association between under 5 diarrhea incidence and meteorological factors in the Central Gondar Zone. The mean monthly temperature and rainfall were positively and negatively related to the incidence of diarrhea in children under 5 years old. The results showed that the observed association between meteorological factors and under-5 diarrhea incidence could be used as evidence for the use of early warning systems for the prevention of childhood diarrhea.

Keywords Diarrhea incidence, Under-5 children, Meteorological factors, Correlation, Ethiopia

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Introduction

Global temperatures are projected to rise by 2 °C or more by the end of the twenty-first century [1], which is expected to impact the incidence of diseases caused by pathogens that can survive or multiply in the environment, including diarrhea [2, 3]. Climate variability is the variation in the mean state and other statistics of the climate on all temporal and spatial scales beyond those of individual weather events, whereas climate change is the long-term significant change in the "average weather" that a specific location experiences [4]. A large percentage of the burden of climate change-related morbidity is expected of children who have unique vulnerabilities to climate change [5]. The World Health Organization (WHO) projects an annual increase of approximately 50,000 child diarrhea deaths worldwide in 2050 attributable to climate change [6].

In sub-Saharan Africa, and Ethiopia in particular, projected climate scenarios show an increase in rainfall variability and temperature as well as prolonged droughts in the region [7]. The World Health Organization (WHO) also stated that in the future, public health may face challenges in controlling infectious diseases due to climate unpredictability, specifically in low-income developing nations. These challenges include temperature, rainfall, and relative humidity [8].

Climate change is expected to increase the frequency and intensity of El Niño periods [9]; in recent decades, El Niño events have been intensifying in the Eastern Pacific [10]. According to a systematic review, although not all diarrheagenic bacteria exhibit this relationship, comprehensive evaluations have shown a positive correlation between temperature and diarrhea incidence, which is the basis for estimates of increased diarrhea mortality as a result of climate change [6, 11, 12]. At higher ambient temperatures, common bacterial infections linked to diarrhea—like diarrheagenic Escherichia coli proliferate quickly. Furthermore, a high temperature prolongs the infections' survivability in the external environment [11, 13, 14]. Droughts and diarrheal disorders are related because of the high prevalence of malnutrition and water scarcity [15, 16]. Lower ambient temperatures favor the growth of viral pathogens that cause diarrhea, such as rotavirus, and these germs' lifespan is prolonged during cooler months [17].

Studies conducted in Ethiopia revealed that increased average temperature, an increased frequency of extreme weather conditions, and a shift in the beginning period of rain either early or late were observed [18, 19]. Diarrhea morbidity is caused by such meteorological extremes and climate variability. The occurrence of diarrheal diseases is predicted to worsen as a result of increased frequency and severity of floods and droughts, declining water quality, and rising rates of malnutrition [16].

The burden of childhood diarrhea is high in Ethiopia and diarrhea is the second leading cause of under 5 deaths in the country [20]. Diarrhea is seasonal and all causes are associated with temperature and rainfall in all countries [11, 12]. These variables have changed over the past decades, and including these variables is important but were not included in most of the previous studies that have been conducted in this study area as a risk factor for under 5 years of diarrhea. Therefore, this study was conducted to fill these gaps and assess diarrhea incidence among children under 5 years of age and associated meteorological factors in the Central Gondar Zone.

Methods

Study design and setting

A time-series ecological study was conducted in the central Gondar zone from 1 January 2013 to 30 December 2022. The Central Gondar Zone is found in the Amhara Region and is geographically located at 170 29'32" North latitude and 420 38'25" East longitude. The mean annual rainfall ranges from 875 to 1025 mm and the temperature ranges from 18 to 35 degrees centigrade [21]. It includes 15 districts and the Gondar city capital of the zone [22]. These districts are namely Alefa, Chilga 01, Nebaru Chilga, East Dembia, Weast Dembia, Gondar Zuria, Lay Armacho, Weast Belesa, East Belesa, Tach Armacho, Central Armacho, Takusa, Tegede, Wogera and Kinfaz Begela. The boundaries are adjoined with the North Gondar zone in the North, the Awi zone in the West and West Gojam zone in the South, the North Wollo zone in the East, and the South Gondar zone in the Southeast [21]. According to 2014 EC zonal health department data, there was 1 referral hospital, 9 hospitals, 406 health posts, and a total of 796 health extension workers. The total population residing in all districts is estimated to be 2,896,928 [23] and according to the 2014 EC Zonal Health Department under-5 age children estimation, there are 297,241 under-5 age children in all districts (Fig. 1).

Sample size determination and sampling technique

All confirmed diarrheal cases among under-5 children reported to the central Gondar zone health department from 2013 to 2022 were included.

Data collection

Data on under-5 children were obtained retrospectively from the Central Gondar Zone Health Department's diarrhea report. Health facilities treat and record under-5 children's diarrhea based on the World Health Organization (WHO) guidelines which define diarrhea as passing three or more loose or liquid stools per day, or more frequently than normal, and offering the treatment. The datasets were subsequently aggregated at the district

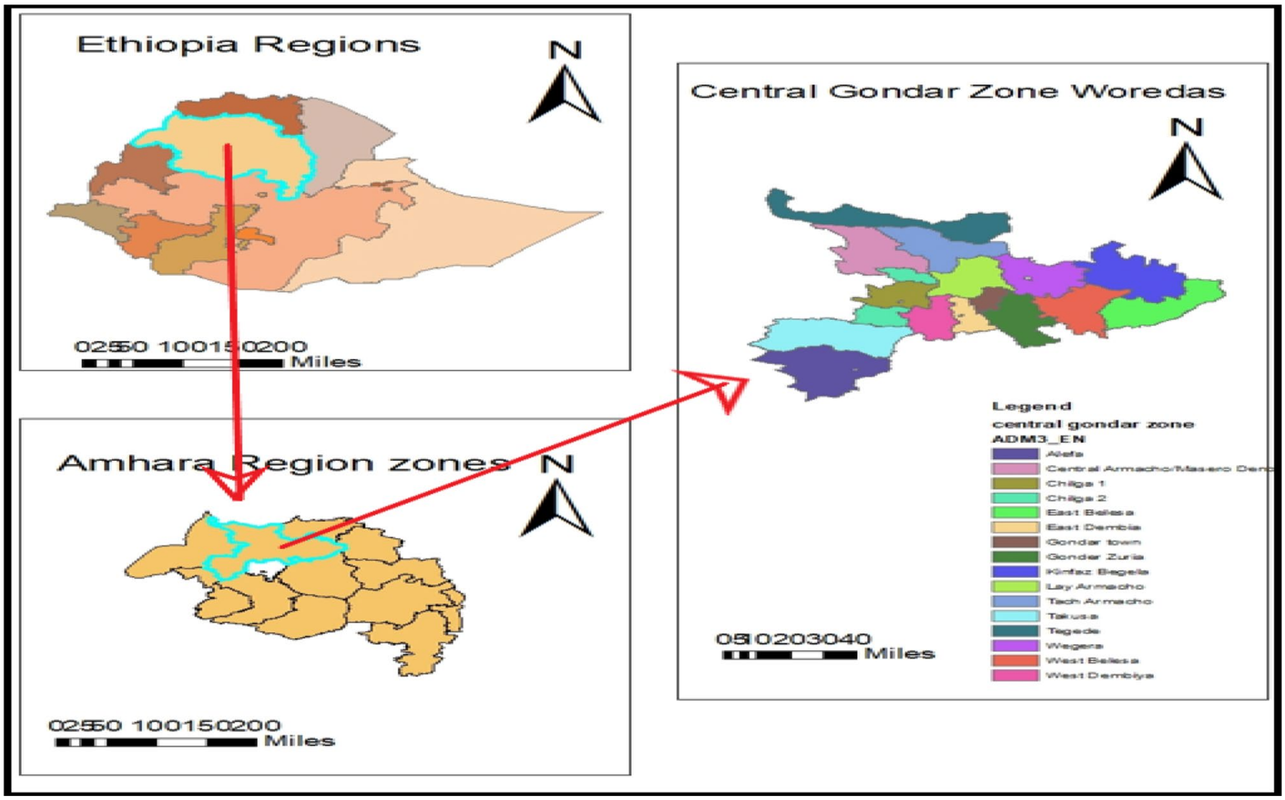

Fig. 1 Map of Central Gondar Zone, Northwest Ethiopia, Ethiopia. The study area map was created by running on Arc Gis version 10.7.1. (https://www.arcgis.com/index.html)

level and patient information was obtained according to age category, sex category, and time of illness (month and year).

Population data for each district for each year were obtained from the Ethiopia Statistics Service. The meteorological data such as the monthly minimum and maximum temperature, monthly humidity, and monthly rainfall of all districts were obtained from the West Amhara Meteorological Directives, Bahir Dar.

Quality control

The data were retrieved from the quarterly surveillance data stored in the Central Gondar Zone Health Department from 1 January 2013 to 30 December 2022. The case data were collected by trained personnel who were familiar with HMIS data management. Meteorological data were collected by trained personnel who know meteorological data management. The data collectors were informed about the research's objectives and data collection procedures. All methods were performed following the relevant guidelines and regulations. After collection, the data completeness and consistency were checked by the principal investigator of the study before analysis. The data were cleaned, edited, checked, and sorted using Microsoft Excel 2021. Further cleaning was performed after importing the data into STATA 14.2 software.

Data management and analysis

The number of under-5 children's diarrhea cases in the population at risk was used to calculate the monthly and annual cumulative incidence of under-5 children's diarrhea during the specified period. The monthly and annual cumulative incidence of under 5 children's diarrhea in each district and the seasonal trends were calculated and line graphs were drawn using Microsoft Excel 2021. The data were subsequently plotted to determine the annual fluctuations in the incidence of diarrhea in under-5 children from 1 January 2013 to 30 December 2022.

The meteorological variables such as average temperature, average rainfall, and average humidity were obtained from the West Amhara Meteorological Office and the data were organized and edited and the graphs were plotted in Microsoft Excel 2021.

Correlation and regression analysis

Bivariate and multivariate negative binomial regressions were performed to test the associations between climatic factors and the incidence of diarrhea in children under 5 years old. A negative binomial (NB) regression accounts for overdispersion by adding a dispersion (variance) parameter to the Poisson model and this regression model can accommodate increased variability [24].

The negative binomial regression model can be expressed as follows:

$$\log(E[Yi]) = \beta 0 + \beta 1\text{X1i} + \beta 2\text{X2i} + \ldots + \beta \text{pXpi} + \gamma 1\text{Yeari} + \gamma 2 \log(\text{Populationi})$$

Where:

- Y_i is the count of the disease in observation i (e.g., in a specific region or time).
- X_{1i}, X_{2i},..., X_{pi} are your primary predictor variables of interest for observation i.
- Year i is the year of observation i.
- Population i is the total population in the area or time of observation i.

And since it's a negative binomial model, the variance is: $\text{Var}(Y_i) = E[Y_i] + \alpha E[Y_i]2$.

Where:

- Log ($E[Y_i]$) is the natural logarithm of the expected count of the disease for observation i.
- β_0 is the intercept.
- $\beta_1,\beta_2,\ldots,\beta_p$ are the coefficients for your primary predictor variables.
- γ_1 is the coefficient for the 'Year' variable.
- γ_2 is the coefficient for the natural logarithm of the 'Population' variable.
- α is the overdispersion parameter.

Spearman's correlation analysis was performed between the incidence of diarrhea in children under 5 years of age and climatic variables by considering 0, 1, and 2 lag months. The multicollinearity between climate variables was checked using the variance inflation factor (VIF) before the multivariable regression analysis and the value was <5.

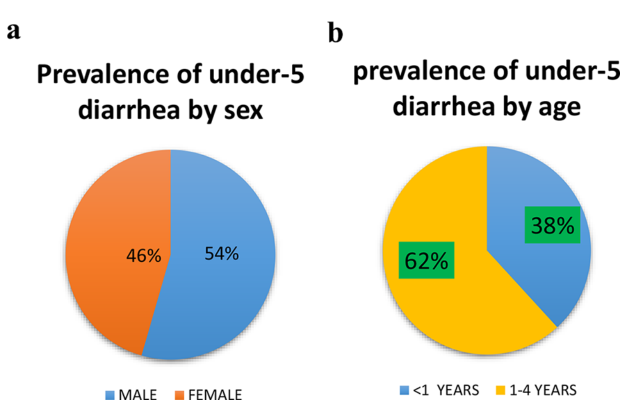

Fig. 2 **a** and **b**. The proportion of patients with Under-5 Diarrhea by sex and age classification respectively in the Central Gondar zone, Northwest Ethiopia

A bivariate negative binomial regression was performed to examine the crude associations between the climatic factors and the outcome variable. In the multivariable negative binomial regression, the adjusted incidence rate ratio (IRR) with 95% confidence interval was calculated to identify the independent effect of each explanatory variable on the outcome variable. A significance level of 0.05 was used for all the statistical tests. aIRRs with 95% CIs were used to determine statistical significance. Statistical analyses were conducted using STATA 14.2 software.

Ethics consideration

Ethical approval was obtained from the Institutional Review Board of the College of Medicine and Health Sciences, University of Gondar (reference number: IPH/2505/2023). A request letter for the required data was written to the Central Gondar Zone Health Department and West Amhara Meteorological Directive Bahir Dar from the Department of Environmental and Occupational Health and Safety and a request letter for the Ethiopian Statistics Service was written from the Institute of Public Health, College of Medicine and Health Sciences, University of Gondar. To ensure the confidentiality of the data, the data were kept secure and were not used for any other purpose.

Result

Distribution of counts of patients with under-five diarrhea by type, sex, and age

Monthly diarrheal morbidity data were collected for all study districts from the 10 years of Central Gondar Zone HMIS data. A total of 527,058 patients with under-five diarrhea were reported during the study period. Non-bloody diarrhea was dominant between 2013 and 2018 (75.33%: 207,717) and functional diarrhea between 2019 and 2022 (80.6%: 202,587). The highest proportion of diarrhea cases was reported among male children (286,806 cases: 54.4%) and between 2019 and 2022 children aged 1–4 years accounted for the largest share (155,016 cases: 61.7%) (Fig. 2a and b).

Trends of under-five diarrhea based on annual incidence rate

There was an overall increasing trend with a yearly fluctuating incidence of under-five diarrhea and there was monthly and seasonal variability. In 2013 under five diarrhea cases had the lowest incidence with an annual incidence rate of 138.5 (38,079 cases) and it reached its peak in 2016 and 2021 with annual incidence rates of 180.9 (52,330) and 177.5 (66,704 cases), respectively (Fig. 3).

There were three under five diarrhea incidence peak months for most years. Overall Figure below illustrates that the incidence of diarrhea among children under

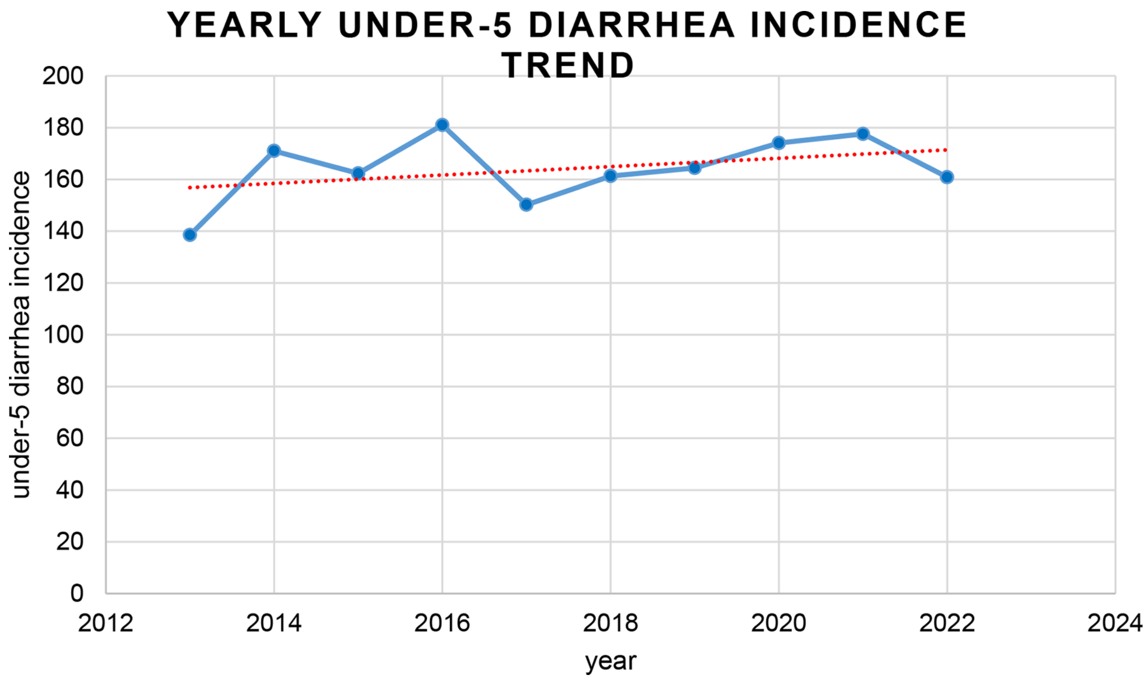

Fig. 3 Yearly trend of diarrhea incidence among under-five children from 2013–2022 in the Central Gondar zone, Northwest Ethiopia

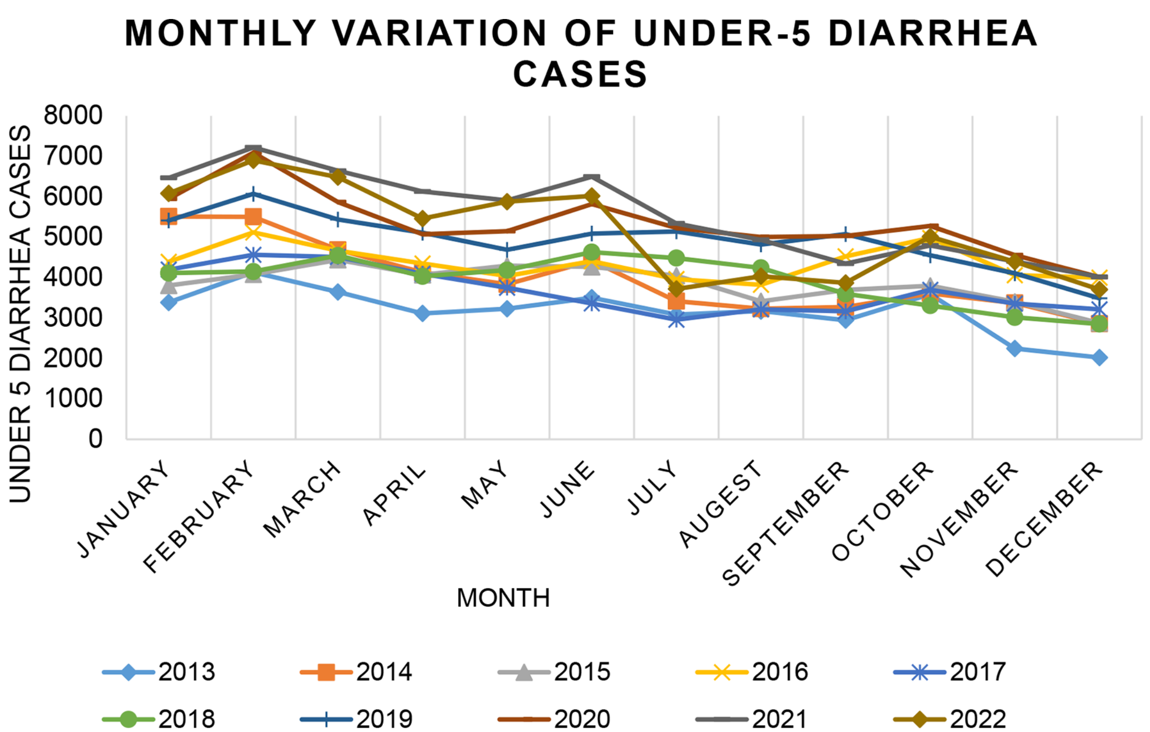

Fig. 4 Monthly and yearly variation in diarrhea cases among children under 5 years of age in the Central Gondar Zone, Northwest Ethiopia, 2023

5 years of age in the central Gondar zone varies in different months of the year. The diarrhea cases decreased between December and January while the highest incidence was recorded in February, followed by June and October (Fig. 4).

The 10-year seasonal trend of the smoothed and deseasonalized under-5 diarrhea incidence was calculated first by using a 12-month moving average and then a central moving average. The trend component was calculated by linear regression between the deseasonalized value and the time code which gives the type of equation Y = ax + b, where Y refers to the trend component of the original value of under-5 diarrhea, a = slope, and b = y intercept. It showed an increasing trend, with an equation of $Yt = 0.027t + 10.9$, which starts to increase in January and reaches its peak in February. The number of diarrhea cases starts to slowly decline over time reaching their lowest peaks in November and December (Fig. 5).

The 10-year average monthly humidity, maximum temperature, and minimum temperature of the study area are indicated in the Figure below. The humidity starts to increase in April and reaches its peak in August. The highest value obtained was 89 $g.m^{-3}$ in Chilga in August 2013. It starts to drop from September to February. A significant reduction was observed in November and the smallest value obtained was 14.1 $g.m^{-3}$ in Alefa January 2017.

The minimum average monthly rainfall was registered in December, January, and February. It starts to rise from May through August and reaches its peak in July. From all observations, the largest peak value was 1175.7 mm in 2021 in lay Armacho. The rainfall decreases from September to December. The monthly average maximum temperature of the study area showed that January, February, March, and April had a higher temperature, where its peak in March and April. The highest value was 31.8 °C in 2021 March in Gondar City. It starts to drop in May and reaches its lowest in July and August and then starts to increase again. The monthly average minimum temperature of the study area showed that it starts to increase from January to April. It reaches its peak in April and May with 14.5 °C in 2020 Gondar city. It starts

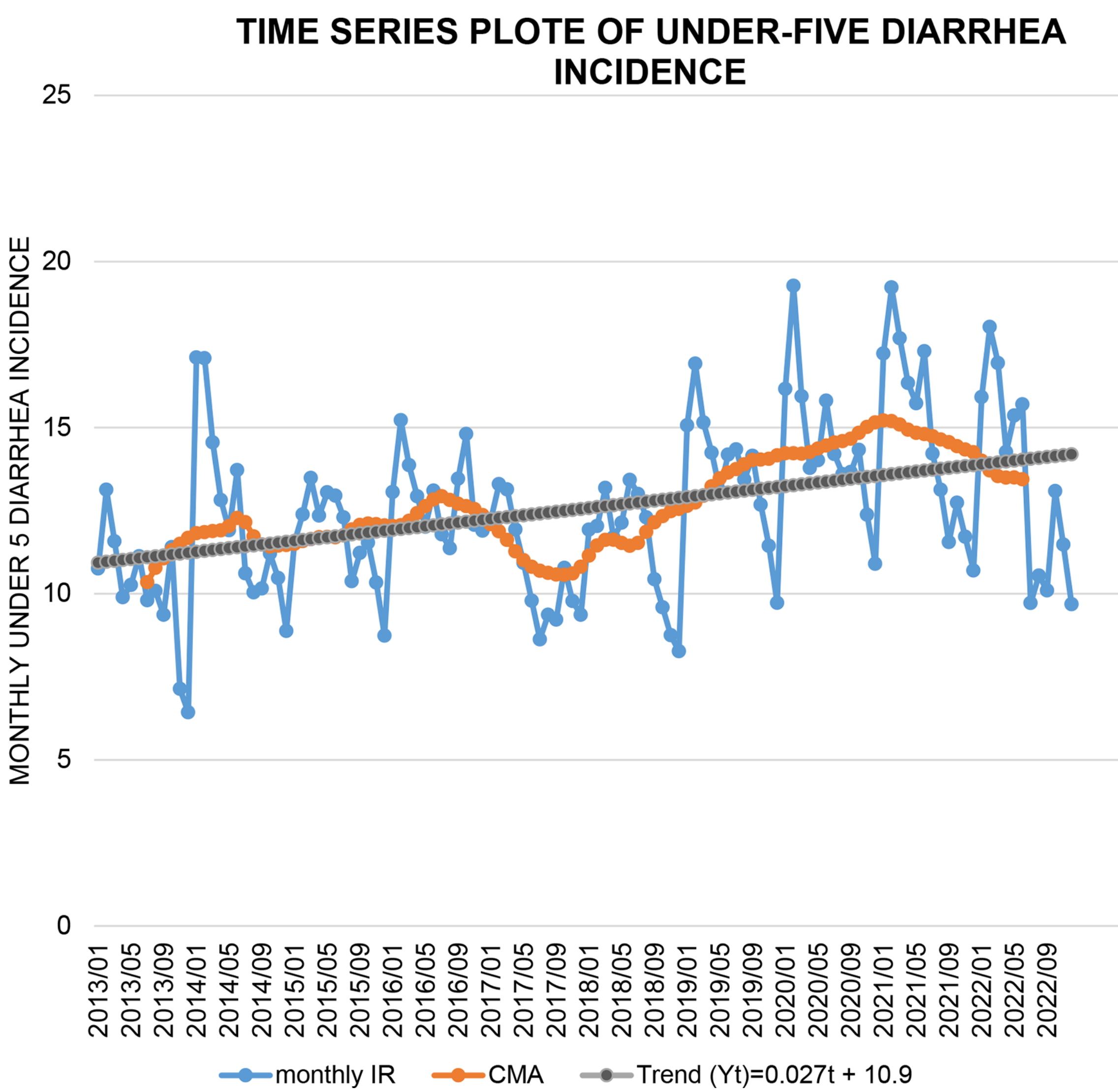

Fig. 5 Trend and seasonal variation in diarrhea incidence among under 5 children in Central Gondar Zone, Northwest Ethiopia between January 2013 and December 2022

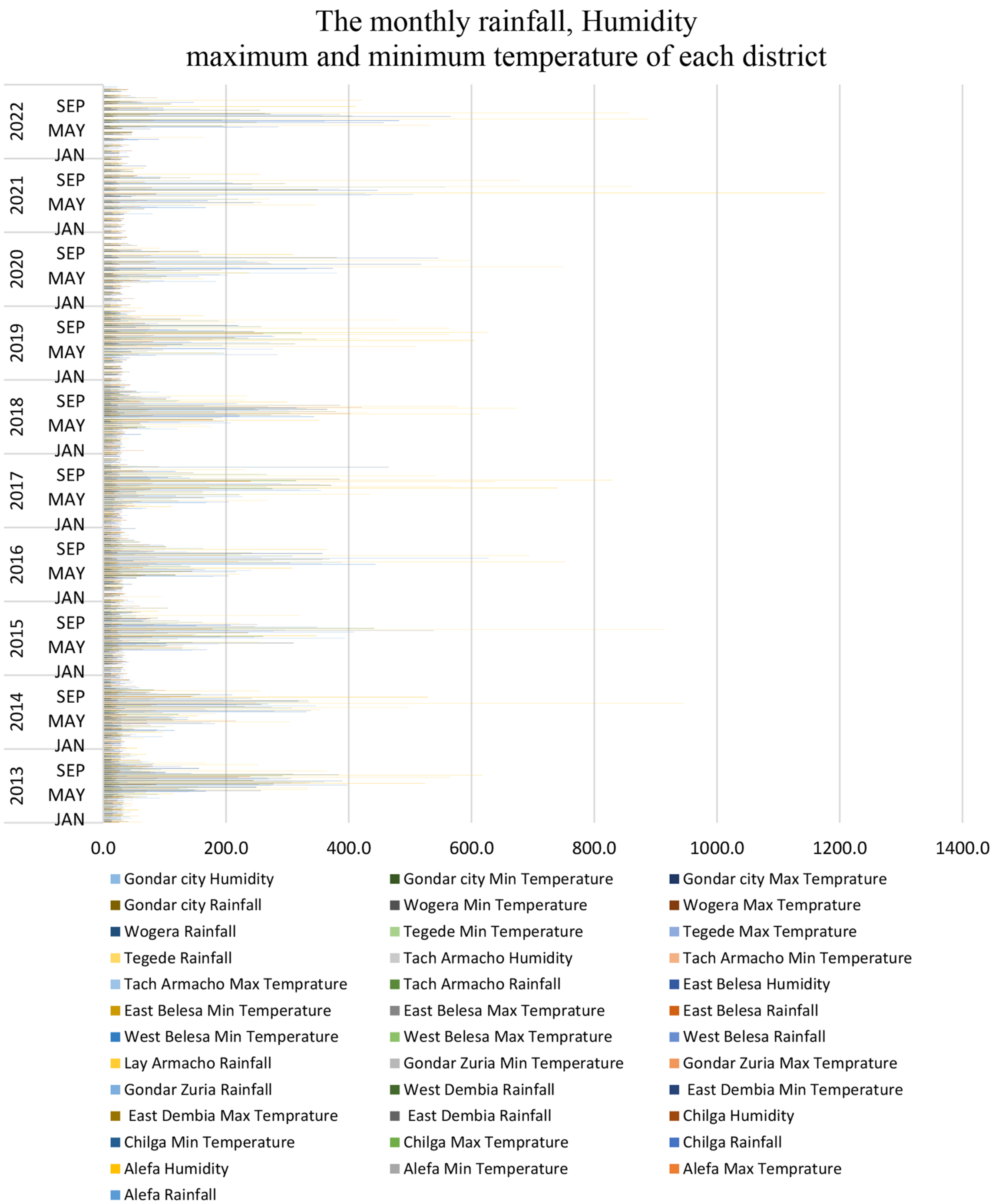

Fig. 6 Monthly and yearly variation of rainfall, humidity, maximum and minimum temperature across districts in Central Gondar Zone, Northwest Ethiopia, between 2013–2022

to drop from October to January and then starts to rise from February to April (Fig. 6).

The pattern of climate variability

Ten years of monthly averages of climatic variables at the study sites revealed that the monthly minimum temperature was 8.73℃ and the maximum temperature was 31.89℃ with an average mean temperature of 21.59 ℃ and ±4.91℃ standard deviation (±SD). The mean monthly rainfall was 122.17 mm ± 172.9 mm (±SD) with a range of 0 to 1175.7 mm whereas, the mean relative humidity (±SD) was 48.2% (±19.37%), with a maximum of 89% and a minimum of 14.1%. The relationships between the incidence of under 5 diarrhea events and average temperature, average rainfall, and average humidity are shown in the figure below (Fig. 7).

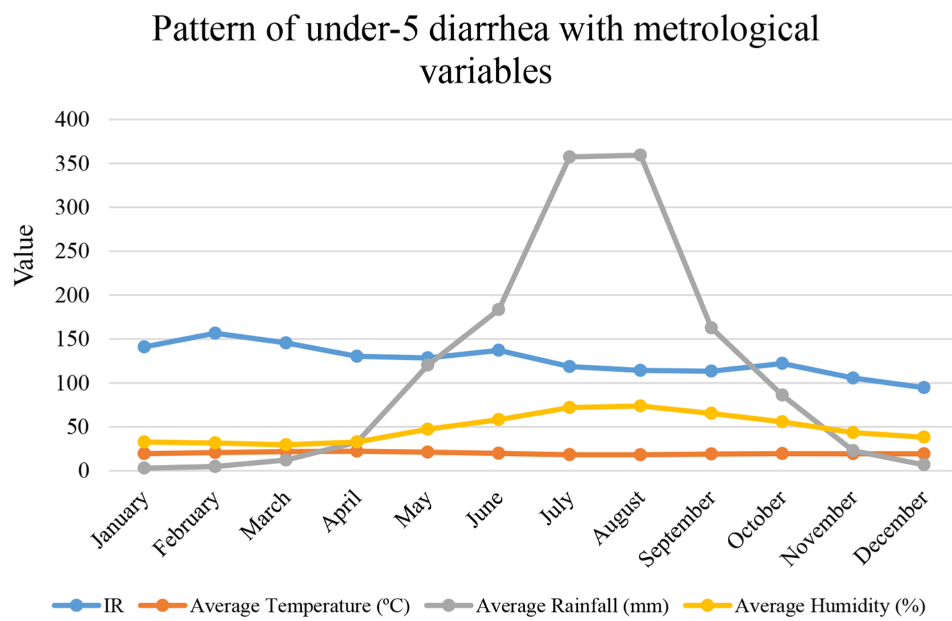

Fig. 7 Relationships between 10-years under-5 diarrhea incidence in months and the 10-year average temperature, average rainfall, and relative humidity in the Central Gondar Zone, 2013 to 2022

Table 1 Correlations between the incidence of under-5 diarrhea and mean monthly Climatic variables in the central Gondar zone, January 1, 2013- December 30, 2022

Monthly mean climatic variables	Lag-months	Spearman's *r*	*P* value
Temperature (°C)	0 months	0.2954	< 0.001
	1 month	0.2693	< 0.001
	2 months	0.2410	< 0.001
Rainfall (mm)	0 months	-0.1023	0.0019
	1 month	-0.1606	< 0.001
	2 months	-0.1753	< 0.001
Relative humidity (%)	0 months	0.0946	0.0518
	1 month	0.0774	0.1126
	2 months	0.0681	0.1647

Effect of climate variability on under-5 diarrhea

Spearman's correlation analysis

Correlation analysis was also conducted to quantify the relationships between the incidence of monthly under-5 diarrhea and climatic variables during the study period, with 0,1 and 2-month lags. Lag correlation occurs when the first metric increases or decreases in sync with the second but with a lag between the first and second metrics.

A significant positive correlation was found between a count of under-5 diarrhea and the monthly average temperature at 0, 1and 2-month lags. The correlation coefficient decreased as the number of lags increased from 0 to 2 months. The monthly mean rainfall and count of under-5 diarrhea were negatively correlated at all time points (0, 1, and 2 months). All lag months were significant and the correlation increased as the number of lags increased. The monthly mean relative humidity and all lag month humidity were positively correlated (Table 1).

Regression analysis

The under 5 diarrhea data showed an overdispersion with mean case of 375.027 and ± 269.943 standard deviation (± SD) which makes it suitable for negative binomial regression model. Multivariate regression revealed that the monthly average temperature and monthly average rainfall were significantly associated with the incidence of diarrhea in patients under 5 years old. There was a significant positive association between the monthly average temperature and the incidence of under-5 diarrhea for 0 and 2 lag months. The Monthly average rainfall and incidence of under-5 diarrhea were negatively associated with 0 and 2 lag months.

There was a significant positive association between the monthly average temperature (IRR = 1.0209; 95% CI (1.0034–1.0387) and the incidence of under-5 diarrhea at 0 lag months. Again, there was a significant positive association between monthly average temperature (IRR = 1.0202; 95% CI (1.0022–1.0385) and the incidence of under-5 diarrhea at 2 lag months.

The monthly average rainfall (IRR = 0.999; 95% CI (0.9985–0.9996)) and (IRR = 0.9992; 95% CI (0.9987–0.9997)) were negatively associated with the incidence of under-5 diarrhea at 0 and 2 lag months respectively. (Table 2).

Table 2 Negative binomial regression analysis of the effect of climate variability on under-5 diarrhea in the central Gondar Zone from January 2013 to December 2022

Monthly mean climate variables	Lag-months	Crude IRR (95% CI)	Adjusted IRR (95% CI)
Monthly average temperature (°C)	0 months lag	**1.0505 (1.0405–1.0606) *** **	**1.0209 (1.0034–1.0387) * **
	1-month lag	1.0473 (1.0371–1.0576) ***	0.9983(0.9765–1.0206)
	2-month lag	**1.0422 (1.0318–1.0527) *** **	**1.0202 (1.0022–1.0385) * **
Monthly average rainfall (mm)	0 months lag	**0.9988 (0.9986–0.9991) *** **	**0.999 (0.9985–0.9996) *** **
	1-month lag	0.9987 (0.9985–0.9989) ***	0.9999 (0.9994–1.0006)
	2-month lag	**0.9987 (0.9985–0.9989) *** **	**0.9992 (0.9987–0.9997) * **

***, p-value < 0.0001

**, p-value < 0.001

*, p-value < 0.05. IRR = Incidence Rate Ratio, 95% Confidence Interval Adjusted IRR 95%CI indicates all the climate variables entered in the final model to investigate the independent effect of each climate variable by controlling the confounding effect between explanatory variables and the outcome variable

Discussion

A time-series cross-sectional study conducted from 1 January 2013 to 30 December 2022 revealed the association between the incidence of under-five diarrhea and meteorological factors in the Central Gondar zone.

Temperature is known to influence transmission intensity through its effects on the growth of pathogens [25] Temperature was significantly and positively associated with the incidence of under-5 diarrhea in this study. These findings are supported by previous studies in southwestern Ethiopia [26], Bhutan [27], and Iran [28] which revealed a positive connection between temperature and diarrhea. The first reason for the increased risk of childhood diarrhea associated with high temperature could be the rapid multiplication and survival of causative agents of diarrhea for longer periods, which occur in warmer months [29]. The second reason may be temporal changes in human behavior during hot weather conditions, such as increased water consumption, the use of unimproved drinking water sources, and decreased hygiene practices due to the scarcity of water since most improved drinking water sources are out of commission during dry seasons [15]. Second, Increased temperatures could lead to food poisoning because food spoils easily in warmer weather [29].

The findings of this study indicate a negative relationship between rainfall and the incidence of diarrhea in patients under 5 years old. This finding is supported by a study conducted in northwestern parts of Ethiopia [30]. The possible reason is that during rainy months there is an increased quantity of rainwater available for other household needs, such as hand-washing, cleaning, or bathing which reduces exposure to diarrheal pathogens [31]. In addition, in the main rainy season there is less movement and contact among people, especially in rural areas and the probability of visiting health facilities is lower [25] mostly in the cold season in particular children tend to stay at home under the care of their parents which reduces the transmission.

A trend toward seasonality shows a seasonal variation of under-5 diarrhea. It starts to increase in January and reaches its peak in February. This is because it is the beginning of the dry season and the average temperature is at its highest. Similar studies have shown that an increase in temperature is positively associated with diarrhea incidence [25, 27]. A shortage of water in the dry season has been associated with an increased incidence of diarrhea [32]. This may be due to the lower availability of fresh water or longer water storage and worsened personal hygiene because of the lower availability of water [33]. The transmission of diarrhea by flies increases as they breed intensively during the pre-rainy season [34].

Another peak incidence was observed in June. The beginning of the rainy season creates a suitable environment contaminating water sources [35] and environmental conditions such as surface runoff and flooding increase the rate of contamination of drinking water sources at the beginning of the rainy season, as the first rainfall events after the dry season wash contaminants from the surface into the water sources [15, 36]. In addition, according to the Zonal Health Department June is the yearly budget closest to the month and all unreported cases might be reported in this month.

The incidence rate starts to slowly decline over time to reach its lowest level from July to September which is referred to as the main rainy season. This finding is similar to that of a study conducted in the northwest part of Ethiopia on the effect of climate on childhood diarrhea [30]. This might be due to the effects of geography, seasonality, and reporting factors where population activities wind down and communications are interrupted, particularly in rural districts [25]. This study identified a slight peak in October. This peak mainly relates to the end of the rainy season and the start of the warm season which favor the growth and survival of bacterial pathogens that cause diarrhea [25]. Excess cases of diarrhea have been reported after heavy rainfall and associated extreme hydrologic conditions such as floods and drought [37]. Again, it is a month that follows September when there are many holidays and celebrities in our culture which may change the way food consumption may lead to diarrhea.

There was also an increasing trend annually during the study period from 2013 to 2022 (131.2, 154.76, 157.1,163.3, 138.4,144.9,145.9, 152.5,155.3,140.1) (Fig. 2).

These findings are similar to those of previous studies in southern Ethiopia on childhood diarrhea where diarrhea incidence increased [38, 39] and studies conducted in resource-limited areas of Ethiopia [40]. This finding contradicts the findings of a study conducted in northwestern Ethiopia which showed a decreasing trend in the incidence of under-5 diarrhea [30]. Potential rebound increases in diarrhea-associated mortality and morbidity are due to increasing urbanization and climate change [11, 41, 42]. Resource limitations, in terms of both availability and program utilization, specifically, incomplete implementation of primary health care units [40] and less exclusive breastfeeding during the first 6 months of life as a key child survival intervention [43] an overall increasing number of population and under-5 populations in each district and improvements in the reporting system both from existing and newly built health facilities, especially in recent years civil war and cost inflation contributed to the overall incremental trend of under-5 diarrhea.

Using under-5 diarrhea cases drawn from monthly under-5 diarrhea reports, and determining the association of incidence of under-5 children's diarrhea and meteorological factors could be important and add value to under-5 diarrhea prevention and control programs [44]. Meanwhile, further studies to investigate the underlying causes of increased risk in the identified areas are recommended, including socio-economical, host factors, and environmental factors, to have a more inclusive view of the under-5 diarrhea incidence risks.

Conclusion

An increasing trend with a seasonal variation in under-5 diarrhea which peaks in February, June, and October was observed. The mean monthly temperature at 0- and 2-month lags was positively related to under-5 diarrhea incidence. The mean monthly rainfall at 0- and 2-month lags was negatively related to under-5 diarrhea incidence. There was no significant relationship between humidity and under-5 diarrhea. To decrease and if possible illuminate the morbidity and mortality caused by diarrhea it is better if precautionary measures are taken since the incidence of under-5 diarrhea has shown seasonality with three peak points in February, June, and October. Further studies to investigate the underlying causes including individual factors, household factors, and environmental factors to have a more inclusive view of the under-5 diarrhea risk.

Strength of the study

This study "Diarrhea incidence among under-five children and associated meteorological factors in central Gondar zone, Northwest Ethiopia" is the first attempt to determine the association of meteorological factors with under-5 diarrhea in the central Gondar zone. Therefore, these findings will serve as a basis for evaluating the progression of under-5 diarrhea interventions in upcoming research projects and provide information for early intervention for the central Gondar health department.

Limitations of the study

The data were obtained from a passive surveillance system. This means that all clinical records did not fully capture the level of Under-5 Diarrhea in the districts because some people may not have reported to formal governmental health institutions and instead used traditional therapy or purchased drugs on their own. Underreporting leads to underestimation of how common the disease is and its incidence. This can lead to inadequate public health planning and resource allocation if the true scale of the problem isn't recognized. As a result, the study may not fully reflect the morbidity of diarrhea among children under five years old in the study area.

Abbreviations

WHO	World Health Organization
ENSO	El Niño and Southern Oscillation
EDHS	Ethiopian Demographic Health Survey
IRR	Incidence Rate Ratio
aIRR	Adjusted Incidence Rate Ratio
VIF	Variance Inflation Factor
NB	Negative Binomial
CI	Confidence Interval
SD	Standard Deviation
HMIS	Health Management Information System
ESS	Ethiopia Statistics Service

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Author contributions

The study was designed by G.Y. H.F, Z.A and L.D participated in the data collection and data processing. Z.G, K.A and G.Y participated in data analysis and interpretation of findings. G.Y prepared the manuscript. All the authors read and approved the final manuscript.

Funding information

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Data availability

The datasets generated during and/or analysed during the current study are available from the corresponding author upon reasonable request.

Declarations

Ethical approval and consent to participate

Ethical approval was obtained from the Institutional Review Board of the College of Medicine and Health Sciences, University of Gondar (reference number: IPH/2505/2023). Informed consent to participate was waived by the Institutional Review Board of the College of Medicine and Health Sciences, University of Gondar (Reference Number: IPH/2505/2023), as the study utilized secondary data on under-five children's diarrhea records from the zonal health department. All methods were carried out following the Helsinki Declarations and guidelines and regulations of the University of Gondar research and ethics review committee. A retrospective study was conducted by taking diarrhea reports from children under 5 years of age from the Central Gondar Zone Health Department. Central Gondar Zone Health Department was contacted and permission was obtained. There were no individual participant identifiers such as names to maintain the privacy and confidentiality of the participants in the study. All the collected records were kept confidential.

Consent for publication
This manuscript does not contain any personal data.

Competing interests
The authors declare no competing interests.

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